Possible Early Dry-Land and Wet-Land Rice Cultivation in Highland North Sumatra

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TRADITIONALLY POLLEN ANALYSTS have only examined pollen and concentrated in particular upon what changes in the tree pollen curves indicate about local and regional vegetation change. Having tracked this, they have made deductions about how swamp and lake-margin vegetation has varied in relation to natural progression or retrogression over time and made palaeoclimatic deductions and deductions about human use of the land. More recently attention has been focused rather more on what the nonarboreal component of each pollen spectrum reveals, and now people are beginning to recognize that the pteridophyte record might also indicate how climate has changed and give signals to possible past anthropogenic activity. Additionally it is becoming increasingly recognized that the analyst must do more than attempt to explain the fluctuations in the pollen and spore records. It is also desirable to count other microfossils that may be present, and these include the biogenic silica (phytoliths, which only a very few people can identify expertly), the algae, microfossil charcoal, leaf cuticular remains, microscopic volcanic ash, and the like. Complete Southeast Asian pollen diagrams alone often contain a very large number of taxa, many of which are ecologically uninformative. The Pea Bullok cores to be mentioned later contained 355 identifiable types in the 70 samples analyzed so far, and other types not yet found in samples from that site are present in those from the other three sites that will be mentioned (Pea Sim-sim, Pea Sijajap, and Tao Sipinggan), despite the fact that they are situated fairly near each other. To present the full data set to nonexperts would be futile, as the pertinent information concerning what the records indicate about vegetation change would be lost in the wealth of technical detail. It is, of course, desirable that the full data set should either be published or submitted to a data bank and be made available to other specialists in due course, and I hope to do this when time permits.

Here I will present the evidence that could be interpreted in terms of macroscale vegetation change, which is probably of climatic origin, concentrating on some selected pollen and pteridophyte spore curves that suggest that many of the changes were not of natural origin and relating these to those microfossil charcoal

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counts that are now available and to the more limited data on the grass phytolith record. The data have their limitations, for example, the lack of charcoal counts from all the cores. Moreover, the samples were prepared specifically for pollen and not phytolith analysis, and only the presence or absence of grass phytoliths is mentioned (counts have been made from Pea Bullok and Pea Sijajap, but inclusion of the full data set here would only add to the detail and restrict understanding of what is important and what is not). At this stage, however, publication of incomplete information is preferable to not publishing at all.

The important points to examine are where and when the main tree taxa rise or fall in representation; if regrowth tree taxa such as *Trema* and *Macaranga* and tree ferns (Cyatheaceae) are better represented when the Lower Montane Forest tree types *(Castanopsis, Quercus, Eugenia, Altingia excelsa)* decline in percentage; if herbaceous elements, particularly grass pollen, are more frequent; and how the regrowth ferns *Dicranopteris* and bracken *(Pteridium)* seem to respond. The gymnosperms and *Symingtonia populnea* tend to be Upper Montane Forest elements, but gymnosperm pollen is readily dispersed over long distances and peaks in the pollen record can represent more open conditions locally.

Bracken is normally the first taxon to regrow after burning on dry rice fields in the area, regrowing from subsurface rootstocks, and *Dicranopteris* is also often an important element in regrowth scrub. Unfortunately most of the regrowth shrub taxa either do not contribute significantly to the pollen curves of modern samples from the area, for example, *Rhodomyrtus tomentosa*, or cannot be identified closely enough. *Eugenia* comp. (comparable to) may include *Leptospermum flavescens*. For instance, *Engelhardia spicata*, a tree that is normally a fairly minor component of Lower Montane Forest, also seems to regrow more abundantly after burning, while *Altingia excelsa,* usually the tallest tree in the forest, may actually increase in significance during clearing phases due to selective conservation or, more likely, because it will not burn and there were no iron tools to fell it. There is in fact only one report of recovery even of a prehistoric stone axe from the Toba area (van der Hoop 1941).

Grasses can grow abundantly on swamps, so high percentages of grass pollen can only be regarded as indicating the occurrence of forest clearance to extend grazing land or to cultivate crops. When the dry-land tree taxa decline, there is evidence for regrowth taxa, and there is a microfossil charcoal record. The implication of decreasing tree pollen, a rise of grass pollen including that in the size range of rice, microfossil charcoal, phytoliths that have taken up carbon due to vegetation burning, and an increase of *Pteridium* and *Dicranopteris* spores and a topography in the vicinity of a pollen site which precludes wet-rice cultivation is that dry rice might have been cultivated. Recognition of wet-rice cultivation is more difficult. The local topography has to be right, but all the other palaeoecological indicators will be the same except that the fern spores are likely to be absent. In the case of both types of cultivation, there is a need to look for microfossil remains of rice itself, cuticular remains with the phytoliths intact, and there is no substitute for excavation and archaeobotanical analysis of remains from archaeological sites where such sites are present and can be excavated. Unfortunately the only possibly old sites in the Toba area are the Batak burial grounds, which outsiders are excluded from entering.

Absolute (independent), as well as relative (percentage), palaeoecological data

are available for the sites mentioned here, but despite the fact that they are well dated by the standards of tropical palynology, insufficient radiocarbon dates are available for a satisfactory level of confidence in the results to be achieved, and there are some technical questions relating to statistical accuracy that remain unresolved, so they will not be presented.

To a large extent, this paper suggests what is possible and indicates where more research might be rewarding. It adds to what is known about vegetation change and agricultural origins in an archaeologically and botanically under-explored area, but it does not pretend to give a definitive answer to what happened in this area of the Toba Highlands in prehistory, although an attempt is made to link in what is known from the few historical accounts which are available.

It is hoped that others will be encouraged to explore the area in more detail in the future for there are certainly enough other good pollen sites to work on there and more cores should be analyzed from the sites considered here. Essentially this is a reappraisal in the light of some additional analyses and experience of pioneer research carried out over 20 years ago but not yet fully published because of the problems of data manipulation and presentation which demand access to a user-friendly, high-powered computer.

INTRODUCTION

Many people associate rice cultivation with water, either with low, sloping bunded fields in river valleys or with terraced hill slopes. With the exception of recent papers by Mudar (1995) and White (1995), this is also true of archaeologists. The long prehistory of drainage in highland Papua New Guinea is well documented from the Kuk site (cf. Bayliss-Smith and Golson 1992), but comparatively little is known about the antiquity of irrigation or tillage, and it is crucial to know this in relation to the origins of rice cultivation in the Southeast Asian islands. The quest to find the origins of rice cultivation in Southeast Asia concentrates mainly on the origins of wet-rice cultivation, of *sawah*, not dry-field cultivation *(ladang)*, although Gorman (1977) and, latterly, White (1995) attempted to model the relationships between the two.

It is unclear when rice was first introduced to highland North Sumatra, but the island has a low number of wild rice species (two, possibly three, all recorded from below 720 m), and the ecological requirements of the crop clearly point toward introduction, while the physical geography of the plateau south of Lake Toba suggests that this was almost certainly as a dry-field crop, as there are comparatively few areas even in recent times where *sawah* was grown. This paper looks at the pollen, pteridophyte, microfossil charcoal, and, less assiduously, the phytolith records that give possible evidence for prehistoric agriculture, considering the results from five pollen cores, one of which is from a lake with a narrow area of land around it which could have been irrigated. The paper tries to put this information in the context of what we know about irrigation and tillage practices of the Southeast Asian past.

When rice was first cultivated in Southeast Asia and whether or not it was always an indigenous development or acquired through some form of diffusion, either of the plant itself, or migration of peoples who used it, is a subject of considerable debate. Pollen and phytolith evidence suggests that rice could have been

grown as early as 6000 years ago in the Bang Pakong Valley of east-central Thailand (Kealhofer and Piperno 1994), while finds of the indica and sinica races were reported from contexts as old as this at Xom Trai Cave in northwest Vietnam (Dao 1985). Other early claims from Thailand have not survived the test of recent scrutiny (cf. Reynolds 1992).

The ever-wet areas of island Southeast Asia have been regarded as regions of recent dispersion of rice varieties adapted to a short day length and a continuously high moisture regime (Bellwood 1985), and it certainly seems to have come late to West Malaysia (Hill 1977). A grain of carbonized rice in a potsherd with parallel ribbed impressions from the Gua Sirih Cave site (Bellwood et al. 1992) gave a calibrated AMS date of c. 4284 B.P., but this pottery may have been imported. Sen (1995) summarized information suggesting that rice was present in sediments from the cave floor, and these are being investigated further. Rice cultivation appears to have been abandoned when the occupation of the cave came to an end, although it revived in the fifteenth century A.D., for reasons that are not yet clear. The earliest other date for rice in island Southeast Asia (c. 3880 B.P.) is from Ulu Leang in south Sulawesi (Bronson and Glover 1984).

It seems to be generally accepted that the agricultural regime in the mountains, particularly in island Southeast Asia, began with shifting cultivation of root crops, followed by the cultivation of rice, but where and when this occurred and what techniques and implements were employed has scarcely been investigated as archaeologists seem more interested in pushing back the date for rice cultivation per se. Most of the island Southeast Asian pollen sites are in the mountains, but these have usually been interpreted in terms of local and regional vegetation change, with the latter regarded as a proxy indicator of climatic variation, and the possible impact of people is regarded as a hindrance to this primary objective. Microfossil charcoal has rarely been counted to trace instances of vegetation burning, which may be of natural or anthropogenic origin, and examination of phytoliths has been neglected.

White (1995) suggested that dry-rice cultivation developed as a "parallel cropping strategy to inundated rice cultivation" but, wisely, did not attempt to put a date on it, as the date is likely to have varied considerably from area to area. She accepted Gorman's view that it had been incorporated into a preexisting swiddening system, and preferred to call it upland or noninundated rather than dry. Swiddening is usually associated with a shifting-field, slash-and-burn cropping technology on dry land and what White calls "a polyculture vegetative structure portrayed as imitative of complex natural tropical ecosystems." However, shifting-field cultivation of wet rice occurs in Borneo, the "wet shifting cultivation" of Seavoy (1973), but not mainland Southeast Asia, and discrete clearing-cultivation-abandonment-clearing of another area cycles are sometimes replaced by rotational use of fields.

It would not be surprising if dry-rice cultivation began earlier in mainland than island Southeast Asia, particularly in places like northern Thailand, Laos, and northern Vietnam than in the ever-wet tropics as the day is longer there and the climate is more seasonal. Rice varieties adapted to poorer soils and drier conditions were grown in what is now part of Vietnam before the eleventh century A.D. (Reid 1995) and were introduced to south China from this source. Reid also stated, without being explicit, that double cropping, use of terracing, and some

irrigation techniques were "almost certainly older" in areas of Southeast Asia than in China. If this is correct, there is no reason why the same could not be true of dry rice cultivation. Indeed, he went on to say that the earliest centers of intensive rice cultivation seem to have been in the intramontane basins of the higher land where there was a dry season, for example, the Kyaukse area of upper Myanmar (Reid 1995 : 96–97). He regarded the shorter dry seasons of the intermontane valleys of the Toba Batak and Minangkabau uplands as slightly less favorable to early elaborations of irrigation systems but suggested that irrigation was practiced at Padang Laws, about 300 km south of the study area, as early as the thirteenth century, although swidden agriculture in the Sumatran highlands is said to be at least 3000 years older, but swiddening of what? No answer is given to this.

Very little archaeological excavation has been carried out in Sumatra, and on the evidence from Tianko Panjang Cave in central Sumatra (Bronson and Asmar 1976), people have only been present for 10,000 years. Information on later occupation is also sparse, mainly dating from about 4000 B.P. onward. According to Bellwood (1985), however, all the peoples of Sumatra appear to be biologically Southern Mongoloid in origin and speak Austronesian languages. He thinks that they migrated southward from Taiwan and reached Sumatra around 4450 B.P. Rice had long been cultivated in China by this time, and the Austronesian speakers presumably brought their crop plants with them, but whether they brought irrigation techniques is another matter.

McKinnon (1991*a*) stated that the Batak, who occupy the Toba area, probably arrived from the Philippines and Borneo between 3000 and 4000 years ago. This is notable in view of the recent evidence for early rice cultivation in Borneo mentioned previously, but McKinnon did not state the sources for this view. While most Metal Age and Protohistoric sites in Southeast Asia have bovid, pig, and dog bones, and often carbonized grains or impressions of rice as well, these are said to be scarce or absent at Tianko Panjang (Bronson and Asmar 1976). Only an interim report was published, so there is no more detail. The only reports on prehistoric archaeology from Sumatra north of the equator, apart from the record of the hand axe from the Asahan Valley, refer to lowland Hoabinhian shell middens found in northeast Sumatra (cf. McKinnon 1991*b*), and these show evidence for a nonagricultural economy.

No prehistoric sites have been found in highland North Sumatra, but Schnitger (1938*a*) claimed that megalithic remains on Samosir, a large neck of land projecting in to Lake Toba, were 1000, possibly 2000, years old, although these cannot be radiometrically dated. Hindu-Buddhist remains are present at Padang Lawas and are thought to date to the tenth to fourteenth centuries A.D. (Schnitger 1936, 1938*a*, 1938*b*), but there is no recent work from the area. McKinnon (1991*a*), however, suggested that there was evidence of trade with northwest India and China. The Padding Lawas region has a long dry season because of the occurrence of a local föhn wind, and if rice was cultivated there in the past, irrigation would certainly have been necessary. Schnitger reported no evidence of fossil irrigation systems, however, and the area has not been reinvestigated more recently.

Results of the new research on pollen sites from the Toba Plateau presented here suggest that human impact on the montane forests in the last 8000 years varied markedly over space and reveals possible evidence for dry-land *(ladang)*

Table 1. Pea Bullok Core A: Estimated Ages, Selected Pollen and Pteridophyte Spore Taxa, Microfossil Charcoal Percentages and Phytoliths

Depth (cm.)	Estimated age (years B.P)	GYMNO-SPERMS	*Syming-tonia* populnea	*Casta-nopsis* comp.	*Quercus* comp.	*Eugenia* comp.	*Engel-hardia*	*Altingia excelsa*	*Ilex*	*Schefflera aromatica* comp.	*Maca-ranga*	*Trema*	*Mela-stoma*	*Rhodo-dendron* comp.
37	2240	2.75	0	2.4	11	2.4	0	2.4	17.87	6.53	0	0	0	4.12
45	2724	1.75	0	14.51	8.77	27.43	0.32	3.67	4.94	0.96	0	0	0.48	0
65	4496	0.3	0	14.73	4.76	22.02	0.89	2.38	4.46	0.15	0.15	0.3	1.34	0
85	6827	2.65	0	3.28	21.76	19.5	3.08	3.9	3.28	0.2	0.2	1.03	1.03	0
95	7963	0	0	4.06	9.28	83.36	0.39	0.58	0.19	0	0	0	0	0
105	8237	9.99	1.9	14.82	17.76	19.14	2.07	5.86	2.41	0.17	0	0	0	0.34
115	8511	13.06	1.17	18.09	19.43	21.94	1	2.68	3.35	0	0	0.17	0	2.34
125	8785	10.87	2.21	13.75	14.6	18.34	3.39	6.11	1.36	0.34	0	0	0	0
145	9332	14.19	1.69	16.72	10.64	16.22	5.57	3.55	4.22	0	0.17	0	0.34	0.34
155	9606	8.88	1.8	24.58	10.55	27.93	3.99	1.29	2.19	0.13	0.13	0	0	0.51
165	9880	12.08	2.25	16.91	13.53	18.2	3.54	4.35	1.93	0.16	0.32	0	0	0
175	10154	10.71	1.69	9.4	21.24	31.77	4.13	2.25	3.76	0	0	0.19	0	0.94
185	10428	14.02	0.83	13.35	15.02	16.36	1.84	5.17	5.17	0	0	0	0	3
195	10702	9.73	1.47	17.54	18.69	28.85	1.64	1.64	3.28	0	0	0.16	0	0.49
205	10976	6.38	1.62	4.86	9.42	9.52	1.11	1.42	0.91	0	0.3	0	0	1.42
225	11523	12.68	2.32	10.18	14.64	14.64	1.43	3.21	3.57	0	0	0	0.18	1.61
245	12697	11.47	1.5	10.81	5.32	25.29	2.66	7.65	2.33	0.17	0	0	0.33	0.17
305	18088	31.49	7.02	6.4	11.36	5.99	1.86	0	1.45	0	0.21	0	0.83	1.24
325	19417	16.46	1.06	5.92	11.42	12.9	0.63	3.17	0	0	0	0.42	0	0.42
345	20164	18.56	1.61	7.23	9.64	2.81	0	5.62	0	0	0	0	0	0.4
355	20247	48.72	0.85	5.08	11.44	3.39	0.42	0.42	1.69	0	0	0	0	0.85
365	20329	26.72	2.16	11.87	11.51	7.55	3.6	1.98	1.26	0.18	0	0	0.36	0.54
375	20412	22.62	2.38	11.9	14.58	9.52	3.57	1.19	0.89	0	0	0	0	0.3
385	20495	28.86	3.98	8.46	9.95	2.49	1.99	0.99	1.49	0	0	0	0	0
395	20578	20.96	1.75	12.66	21.83	7.86	0.87	0.44	0.87	0.87	0	0	0	1.31
405	20660	26.84	1.05	9.82	13.33	4.56	4.91	1.23	2.46	0.17	0	0.17	0.17	0.53
415	20743	54.04	0.46	6.23	4.85	2.08	2.77	2.31	0	0	0	0	0	0
425	20826	36.3	1.07	4.63	12.45	0.53	0.71	1.07	0.53	0	0	0	0	0.18
435	20909	13.57	0.93	16.17	14.13	6.88	4.83	1.49	2.04	0.19	0	0.19	0.19	0
445	20992	13.48	3.04	11.74	5.65	2.17	3.48	2.61	0.43	0	0	0	0	0.87
455	21121	5.39	2.99	28.34	18.76	11.98	2.39	4.79	1.6	0.4	0	0	0	2.59
465	21250	28.18	0.91	8.36	6.54	1.64	5.82	3.09	1.27	0	0	0	0	1.09
475	21379	44.91	1.37	6.64	9.76	3.52	3.32	1.56	0.98	0.39	0.19	0.19	0	0.98
485	21773	11.89	0.39	8.79	6.83	2.93	10.87	0.78	1.37	0	0	0	0	0.19
495	22168	31.09	1.04	8.29	7.77	2.59	5.7	2.42	1.21	0.34	0	0	0	0.68
505	22562	15.59	2.12	11.75	17.15	11.17	6.74	2.89	4.62	0	0	0	0	1.73
515	22957	67	0.33	2.64	10.23	1.32	0.99	2.31	0.33	0	0.33	0	0	0.66
525	23351	36.19	0.34	10.98	9.09	13.89	7.2	1.2	1.37	0	0	0	0	1.2
535	23745	85.06	0	3.83	3.06	1.15	1.72	0.57	0	0	0	0	0	0.57
545	24140	66.21	0	7.17	6.78	3.92	2.06	0.88	0.2	0.49	0	0	0.1	0.59
555	24405	39.96	0.63	7.4	10.78	2.11	1.27	6.13	1.69	0	0	0.21	0	0.42
575	24937	42.9	0	7.72	12.34	6.17	1.54	6.17	0.31	0	0	0	0	0.31
585	25202	52.17	0.62	4.66	13.35	1.55	0.62	4.04	1.24	0	0.31	0	0	0.31
595	25467	35.14	1.27	5.43	13.77	3.08	1.09	6.52	2.35	0.54	0	0	0.36	0.18
722	28840	12.78	2.16	28.2	11.86	2	1.08	2.16	1.54	0	0.15	0	0	0.31
727	28853	10.96	2.48	23.11	10.44	4.18	1.3	1.17	3	0.26	0.13	0.13	0.52	0
787	30565	26.87	3.05	16	8.76	3.05	1.52	3.43	1.52	0.2	0	0	0.57	0.2

Pollen sum total dry land pollen plus Cyatheaceae spores. Selected taxa shown only.

(Extension of Table 1.)

Vaccinium comp.	AMAR-ANTH-ACEAE	URTIC-ACEAE/ MORACEAE	*Myrsine*	GRAMIN-EAE	CYATHE-ACEAE	*Dicran-opteris*	*Pteridium*	*Lyco-podium cernuum*	Pteridophyta as % of total pollen	Charcoal as % of total pollen	Phytoliths
5.5	0	0	21.99	0	7.56	3.43	0	0	729.37	12.27	Panicoid, anvil, carbonised
2.71	0	1.75	7.5	2.39	3.83	1.27	0	0.64	247.72	1.04	Present
2.08	1.04	3.12	7.74	6.25	2.68	0	0	0.89	132.66	3.19	Present
0	0	2.26	9.24	1.03	1.23	0	0	0.82	195.71	2.68	Sparse
0	0	0.19	0.19	0	0.19	0	0	0	17.99	0	?
2.07	0	0.86	5.69	0.34	6.2	0.5	0	0	226.86	0.84	Sparse
1.17	0	0.17	1.51	0	7.54	0.5	0	0	276.48	0.35	Sparse
2.55	0	0.68	8.15	0.17	5.43	0	0	0	191.88	0	Sparse
2.03	0	1.01	3.72	0.84	6.11	0.34	0	0	193.55	0.68	Absent
0	0	1.54	5.79	0.13	2.57	0.26	0	0	146.49	0.25	Sparse
1.29	0	2.09	4.02	0.8	5.47	0.8	0.16	0	168.1	0.48	Absent
2.44	0	0.94	4.7	0	6.01	3.95	0	0.37	208.65	0.18	"
1.84	0	0.5	3.17	2.17	5.17	0	0	0.17	230.76	0.16	Sparse
0.82	0	0.33	2.46	0	5.57	0	0	0	146.05	0.17	Panicoid, sparse
1.42	0.1	0.71	3.55	0.91	5.97	0	0.1	0.2	178.5	0.73	Absent
1.43	0	1.43	6.78	0.36	11.97	0	0.18	0	220.22	0	Panicoid, anvil, sparse
1.5	0	0.33	5.49	0.66	8.15	0	0	0	194.95	0.5	Absent
4.34	0	0	4.54	1.45	9.5	0	0	0	90.29	0.21	Sparse
6.76	0	0.84	6.98	1.27	12.26	0.21	0.21	0.21	119.8	1.96	Panicoid, sparse
11.24	0	0.8	14.06	1.61	22.09	0.4	0	0	114	0.4	Absent
7.63	0	0	4.66	0	9.32	0	0	0	199.12	0	Absent
9.53	0	0.9	7.73	0	7.19	0.54	0	0.18	129.39	0	Anvil, etc., sparse
9.82	0	0	4.76	0	12.21	0.3	0	0	60.23	0	Sparse
11.44	0	0.5	7.96	0	17.41	0	0	0	140.44	0.44	Absent
4.37	0	1.31	10.04	0.44	11.35	0	0	0	151.67	0	Panicoid, anvil, sparse
8.42	0	1.58	9.12	0	7.02	0	0	0.35	93.15	0.49	Absent
9.24	0	0.23	8.08	0	7.39	0	0	0.23	55.34	0	Anvil, etc., sparse
21.53	0	0	10.14	0	5.52	0	0	0.35	49.56	0.52	Absent
7.25	0	1.86	10.97	0.37	12.25	0.56	0	0.37	88.67	0	"
32.17	0	0	9.13	0.43	9.53	0	0	0	135.16	0.39	"
6.39	0	1.2	2.99	0	1.2	0.2	0.2	0	112.13	0	Panicoid, etc., sparse
18	0	0.36	4.73	0.54	13.27	0.36	0	0.18	111.04	0.67	Absent
5.86	0	0.39	4.88	0	11.33	0.19	0	0.19	149.26	0	"
21.68	0	0.98	8.2	0	13.87	1.37	0	0	127.86	0	"
12.43	0	0.52	6.91	0.52	7.74	0.17	0	0	98.74	0.18	"
6.16	0	0.77	3.66	0.38	5.97	0	0	0	168.34	0.93	Sparse
0.33	0	3.3	1.98	0.33	5.28	0.33	0	0	45.32	0	Sparse
1.2	0	1.03	4.46	0.86	6.68	0	0	0.34	186.28	1.26	Absent
0	0	0	0.77	0	1.72	0	0	0	79.73	0	"
0.78	0	0.39	2.85	0	3.93	0	0	0.2	101.7	0	"
3.38	0	0.63	6.34	2.75	8.45	0	0	0	104.39	0.23	Panicoid, sparse
1.23	0	0.31	4.29	5.82	6.44	0	0	0	100.67	1.31	Anvil, etc., sparse
2.48	0	0.31	1.24	0.93	7.75	0.31	0	0	70.69	0	Present, sparse
1.27	0	0.18	6.34	1.63	8.19	0.18	0	0.18	81.85	4.33	Absent
1.54	0	0.92	9.86	6.16	6.32	0.31	0	0	52.41	14.47	Sparse
1.83	0	0.13	8.75	1.17	14.22	0	0	0	61.4	3.07	Absent
0.57	0	0.38	15.81	0	9.72	0.38	0.2	0.2	109.9	1.88	Anvil, etc., sparse

and wet-land *(sawah)* rice cultivation rather earlier than might be expected for a highland, almost ever-wet tropical area.

Earlier work at Pea Sim-sim suggested that swamp forest disappeared abruptly around 6500 years ago (Maloney 1979). Examination of additional pollen samples discussed later shows that deforestation was more gradual until about 2500–2000 B.P. The other two swamps considered (Pea Sijajap and Pea Bullok) and Tao (Lake) Sipinggan contain evidence for intensive forest clearance about this time too. Three of the sites reveal that grasses were burned, and the records from two long cores from Pea Bullok suggest that, when the radiocarbon dates are corrected, forest disturbance began about 8000 years ago. Evidence for crop cultivation is scanty. Yam pollen has never been reported from the fossil pollen record, although taro pollen has recently been found at Kosrae in Micronesia (Ward 1995), but biogenic silica in carbonized leaf fragments from Pea Sijajap and disaggregated biogenic silica with carbon inclusions from Pea Sim-sim hint that the later clearances were for rice cultivation. In the latter case, the circumstantial pollen and pteridophyte spore record and its likely source area suggest *ladang* rather than *sawah*. The records from all of these sites will be outlined in a little more detail later, without getting too technical, and the relevant data from the five sites are presented in Tables 1–5, with a summary showing when grass pollen was an important contributor at the main sites in Table 6. The estimated dates have been calculated assuming constant peat accumulation or sediment deposition between the radiocarbon dates levels and ignoring inverted dates.

REGIONAL BACKGROUND

All except one of the pollen sites discussed here are at about 1400 m altitude on the plateau south of Lake Toba (Fig. 1). Pea Sijajap, in the downfaulted Simamora Valley, southwest of Pea Sim-sim and Tao Sipinggan, at an elevation of 1300 m, is the only one that is not. Pea Bullok is situated about 2 km north of Siborongborong, about 15 km east of the other sites.

In 1974, when the cores were collected, the Toba Plateau was almost totally devoid of forest. Disturbed Lower Montane Forest was present at Silangit and Bahlimbanabolon and there was some scrubby forest in a ravine below Huta Ginjang, the highest peak in the region. Some of the Simamora Valley was under *sawah*, there were some bunded fields on the plateau itself, and ponded fields in the narrow valleys cut into the soft Toba ash. There were small areas of sweet potato and other root crops, a variety of fruit trees were grown along road and track sides, and new crops had been introduced, particularly pineapples. A large *Pinus merkusii* plantation was present north of Pea Bullok, and a small plantation on the northwest slopes of Tao Sipinggan, but the main impression was of a land too marginal for anything except shifting cultivation of rice, although European vegetables were also grown on dry fields. Particularly around Lintongnihuta and on the escarpment slopes facing Lake Toba, land abandonment was common, and some land had been abandoned so long that people could not remember to whom it had belonged.

The soils consist of rankers, very shallow acid brown earths and podzols, human-induced surface water gleys, and terrace soils which vary in form according to the parent material. Terrace soils with a Toba tuff parent material were

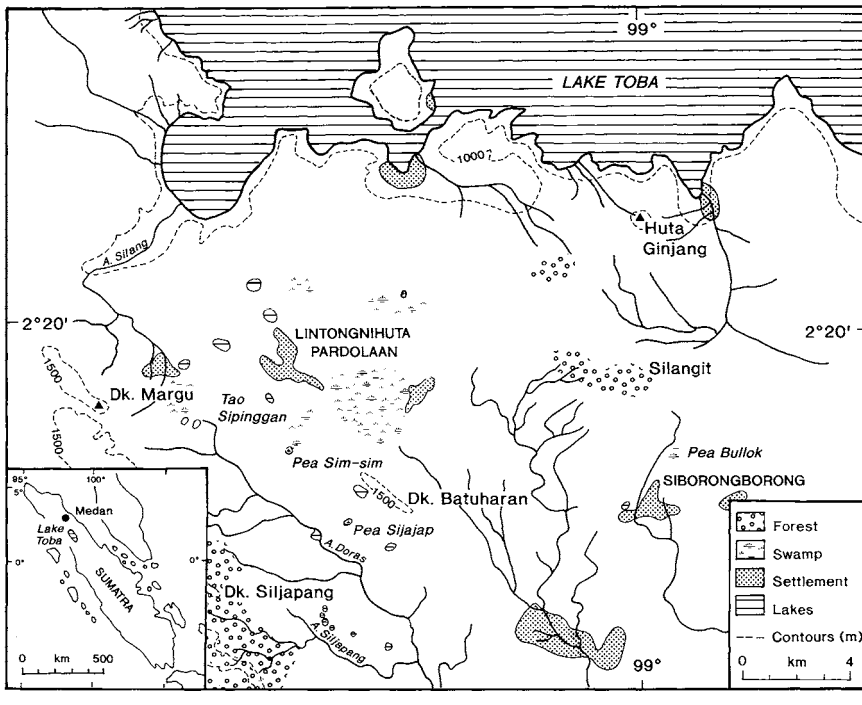

Fig. 1. Location of the North Sumatran pollen sites considered in the text.

found between Siborongborong and Lintongnihuta, and those with admixtures of older sedimentary rocks on the land facing Toba. The shallow mountain soils of Huta Ginjang were derived from older sedimentary rocks. Reclaimed peats and alluvium provided the parent material in the Simamora Valley.

Except around Lake Toba itself, which is in the rainshadow of both the northeast and southeast monsoons, precipitation is above 2000 m with between one and three slightly drier months per annum, sufficient for lower montane forest to grow. So this is a land that would naturally be forested.

THE PALAEOECOLOGICAL RECORD

It is necessary to outline the evidence for vegetation changes from each site separately before drawing the data together and reaching conclusions about land-use changes. Undoubtedly some of the vegetation disturbances were of natural origin, but there is strong circumstantial evidence that many of them were not, and this becomes accentuated when the individuality of the records for all except the most recent samples are taken into consideration.

Pea Bullok

Pea Bullok (1400 m) is a herbaceous swamp that almost completely infills an extinct volcanic crater. There is no land nearby which could be used for *sawah*,

Table 2. Pea Bullok Core B: Estimated Ages, Selected Pollen and Pteridophyte Taxa, Microfossil Charcoal Percentages and Phytoliths

Depth (cm.)	Estimated age (yrs B.P.)	GYMNO-SPERMS	*Syming-tonia populnea*	*Castan-opsis* comp.	*Quercus* comp.	*Eugenia* comp.	*Engel-hardia*	*Altingia excelsa*	*Ilex*	*Schefflera aromatica* comp.	*Maca-ranga*	*Trema*	*Mela-stoma*	*Rhodo-dendron* comp.
20	892	0.9	1.22	3.45	2	0.91	0	1.74	1.45	0.35	0	0	5.82	0.18
25	1116	1.02	0	5.41	4.57	11.34	0.68	0.51	0.17	25.72	0.17	0	1.01	2.88
35	1562	5.23	0.77	19.77	21.9	28.88	3.49	3.68	1.94	0.19	0.58	0	0	0.58
45	2008	0.97	0	6.19	3.91	15.96	1.14	0.81	8.79	4.56	0	0.16	0	0
77	3426	4.48	0	8.95	30.35	9.95	0.99	5.47	0.99	0.5	0	0	0	0
105	4686	4.86	0.52	6.77	8.33	13.89	0.69	1.56	7.46	9.03	0.35	0.35	0.17	2.6
115	5132	7.7	0.38	15.8	20.04	18.5	4.05	1.16	3.85	1.73	0	0	0	0
125	7202	8.72	2.23	17.07	15.21	28.2	3.71	1.85	2.97	0	0	0	0	0.37
135	9273	8.37	2.14	23	11.31	33.33	2.34	0.58	2.53	0	0	0	0	0
145	10579	15.21	1.74	17.25	16.66	25	1.16	0.77	5.43	0.19	0	0	0	0.97
155	12009	56.86	0.2	5.17	7.95	4.77	0.79	0	2.78	0.4	0.2	0	0	0.2
165	13439	45.54	1.61	6.96	8.03	0.53	0.89	1.61	3.93	0	0	0	0	1.61
175	14868	73.94	0.96	4.25	3.47	0.58	0.39	0.19	0.19	0	0	0	0	0.39
185	15366	70.78	0.95	2.09	3.79	1.33	0.19	0.38	0.19	0	0	0	0.19	0.95
195	15864	27.12	1.45	15.94	16.15	0.62	0	0.41	4.97	0.21	0	0.21	0.41	1.45
205	16363	39.79	3.56	3.96	9.9	1.39	0.2	1.78	2.97	0	0	0.2	0.99	2.97
215	16861	31.16	2.6	7.98	14.47	8.72	2.41	1.85	2.41	0	0	0	0	2.04
225	17360	58.63	1.57	6.47	4.7	7.06	1.76	0.39	1.57	0	0	0	0	0.59
235	17859	47.72	3.55	4.06	9.14	3.55	2.54	2.03	0.51	0.51	1.01	0	0	0
245	17950	24.12	3.3	12.5	14.58	3.64	1.04	0.35	1.39	0	0	0	0.17	0.17
255	18041	21.68	2.33	12.45	18.48	3.31	3.31	1.75	0.97	0	0	0	0.19	0.19
265	18132	34.34	0.68	13.2	14.21	6.26	3.04	3.89	1.86	0.51	0.51	0	0.17	0.85
275	18223	27.9	2.58	16.66	13.23	3.95	6.53	2.59	1.2	0.17	0	0	0	0.17
285	18314	18.36	1.31	25.76	9.61	3.93	0.87	2.18	0	0	0.44	0	0	0
295	18405	20.03	3.97	18.65	14.33	6.22	4.66	0.52	0.17	0	0	0	0	0
305	18496	34.13	3.17	7.34	10.71	11.31	2.78	1.78	2.18	0	0	0	0	0.2
315	18690	30.28	3.17	13.03	18.66	7.39	4.58	1.76	0.7	0	0	0	0	0
325	18884	38.81	2.95	10	14.28	2.95	1.48	1.48	0.49	0	0.49	0	0	0
335	19079	25.09	3.65	9.36	14.6	0	5.11	2.92	0	0	0	0	0	0
345	19273	30.87	1.22	10.22	16	10.78	3.83	1.74	2.61	0.35	0	0	0	0.17

Pollen sum total dry land pollen and Cyatheaceae spores. Selected taxa only shown.

and most of it has been reforested with pine. Eighteen radiocarbon dates have been obtained from two cores from the site, the oldest from North Sumatra. Core A from the edge of the swamp extends back over 30,000 years, but not continuously. Core B from the center is more than 20,000 years old at the base. The older sequences from the cores have been discussed in Maloney and McCormac (1996*a*, 1996*b*). Neither core has a high sampling resolution for the later Holocene. The early-middle Holocene pollen record of Core A (Table 1) is dominated by Lower Montane Forest and the high pteridophyta: pollen ratio suggests that the climate was ever-wet with temperatures no higher or lower than at present. A very high peak of Eugenia type occurred around 8000 years ago, followed by a rise of open indicating Urticaceae-Moraceae and Gramineae pollen, while significant peaks of *Myrsine* and *Ilex* around 3300 B.P. may represent replacement of swamp forest by scrub vegetation as a result of natural or anthropogenic vegetation change. The course of forest decline cannot be traced with precision, but the charcoal content as a percentage of total pollen was generally very low, so natural or anthropogenic burning might not have been important. There was a charcoal peak in the c. 2240 B.P. sample, and Panicoid grass phytoliths, some

(Extension of Table 2.)

Vaccinium comp.	AMAR-ANTH-ACEAE	URTIC-ACEAE/ MORACEAE	*Myrsine*	GRAMIN-EAE	CYATHE-ACEAE	*Dicran-opteris*	*Pteridium*	*Lyco-podium cernuum*	Pteridophyta as % of total pollen	Charcoal as % of total pollen	Phytoliths
7.45	0.18	4.18	43.27	2.91	1.64	1.64	18.73	0.36	184.38	153.27	Panicoid, etc., carbonised
0.17	0	3.22	13.2	4.74	3.55	0.68	6.26	0.17	211.22	0.69	Anvil
0.97	0	1.74	0	0.31	1.93	0.19	0	0.39	193.87	0	Anvil
0.16	0	0.98	42.67	1.14	1.46	0.32	0	0.81	76.2	0.16	Anvil, carbonised
4.48	8.95	3.98	2.49	0	9.44	0.5	0	0.99	639.9	0	Anvil
1.04	0.17	0	14.41	1.56	5.38	0	0	0.35	175.14	6.3	Anvil, carbonised
1.35	0	0.58	5.39	0	6.74	0.19	0.19	0.19	241.52	0.6	Monocot
0.93	0	0.37	5.56	0	4.81	0.56	0	0.18	180.07	0	0
0.19	0	1.17	4.29	0	3.51	1.36	0	0	132.88	0	0
0.1	0	0	3.1	0	9.3	1.16	0	0.19	305.28	0	Monocot
0.79	0	0	6.56	0	11.53	0	0	0	130.11	0	0
1.43	0	0.18	2.68	0	23.14	0	0	0	182.86	0	0
1.54	0	0	1.93	0	10.43	0	0	0	56.89	0	0
0.38	0	0	0.57	0	16.51	0	0	0	104.61	0	0
2.07	0	0	5.38	0.41	16.97	0	0.62	0	177.15	0	0
4.95	0	0.2	2.77	0.4	13.66	0.99	0	0	161.46	0.21	0
2.97	0	0.93	5.94	0	14.47	0	0.18	0	233.54	0	Anvil
2.94	0	0.78	3.33	0	7.06	0	0	0	72.58	0	0
1.52	0	1.01	4.57	0	15.23	0	0	0	85.42	0	Monocot
6.77	0.17	4.34	9.89	0.87	6.62	0	0	0.52	61.76	0.16	Monocot
4.28	0	0.97	4.47	0.39	20.42	0	0	0.19	66.61	0	0
2.88	0	1.52	4.57	0.34	5.07	0.17	0.34	0.34	94.84	0	0
4.98	0	1.72	6.53	0	6.69	0	0.17	0.17	88.52	0	Monocot
7.86	0	4.37	7.42	0	9.61	0	0	0	62.65	0.66	Monocot
19.86	0	0	2.07	0.34	6.38	0.17	0	0	37.74	0	0
3.17	0	0.99	5.75	0.2	12.69	0	0	0	79.77	0	Monocot
1.41	0	0.35	4.93	0	9.16	0.35	0	1.76	82.93	0	Monocot
3.94	0	0	6.4	0	10.83	0.49	0	0	74.06	0.47	Monocot
5.84	0	1.46	10.95	0	16.06	0	0	0	52.2	0	0
4	0	0.87	6.61	0	7.47	0.17	0	0.35	136.88	0	Panicoid

with carbon inclusions, which could be from rice, were present, but reliable identification is dependent upon the occurrence of phytoliths within cuticular remains. Panicoid grass phytoliths were also present in six other samples, all predating 10,000 B.P., and could therefore be from swamp grasses.

The last 20,000 years of vegetation change in Core B is represented by only 3.5 m of peat accumulation. Here the main rise of *Eugenia* began before 9200 B.P. and its decline before 5100 B.P. (almost 6000 B.P. cal. using Pearson et al. 1986). However, the forest pollen percentages generally declined prior to this, perhaps 8000 years ago, suggesting that natural or anthropogenic disturbance was occurring. As *Eugenia* decreased before 5100 B.P., pollen resembling *Schefflera aromatica*, a regrowth shrub/small tree, and *Myrsine*, a likely swamp element, increased, confirming that swamp forest was replaced by scrub vegetation possibly due to the impact of people. Perhaps the dry-land forest had been cleared so much that the wood from swamp trees was needed, as seems to have occurred at Kuk and at the Pea Sim-sim site, which will be discussed later. Both these taxa remained important at the top of the diagram indicating the disturbed nature of the recent vegetation. Weed Amaranthaceae pollen was present in two samples, the oldest of which dates to c. 3400 B.P. Amaranthaceae can be weeds of wet-rice fields but

Table 3. Pea Sim-Sim: Estimated Ages, Selected Pollen and Pteridophyte Spore

Depth (cm.)	Estimated age (yrs B.P.)	GYMNO-SPERMS	*Castan-opsis* comp.	*Quercus* comp.	*Eugenia* comp.	*Engel hardia*	*Altingia excelsa*	*Maca-ranga*	*Trema*
0	0	11.5	2.65	16.81	9.73	0	4.42	5.31	0
5	167	22.08	7.84	13.23	0	1.96	8.33	4.41	0
15	500	14.17	4.72	12.6	0	1.57	7.87	0	0
25	833	3.45	4.71	22.64	15.41	0.94	5.34	1.57	2.51
35	1167	8.51	4.68	8.94	0	0.85	17.45	0	0
45	1500	19.04	1.73	14.29	0.87	0.43	12.12	0.87	0
55	1833	32.06	3.05	0.38	1.14	3.82	11.83	0.38	0
60	2000	13.55	0	13.56	1.69	0	6.78	6.78	5.08
65	2167	20.86	6.36	6.36	0.79	4.97	4.17	8.75	0.4
75	2500	2.91	0	4.85	1.94	0	6.79	0	1.94
77	2567	32.08	2.25	12.94	1.69	0	9.19	1.5	0.19
105	3500	3.58	21.27	19.68	18.49	1.19	4.17	0.99	0
110	3667	1.64	16.41	20.45	5.56	7.7	10.61	0.63	1.14
125	4167	5.35	4.28	18.72	12.3	2.14	10.16	1.6	0.53
160	5333	9.5	3.52	42.96	9.51	3.17	13.03	1.41	0.35
175	6663	2.48	1.65	18.26	49.8	0	3.3	0	0.83
210	7793	2.74	0	6.85	5.48	1.37	2.74	0	0
225	8085	2.32	1.16	16.28	34.88	2.91	1.74	0	0
260	8588	1.98	5.95	10.6	49	3.64	1.65	0.66	0.33
275	8856	0.4	4.83	7.04	62.57	2.21	1.61	0	0
310	9482	1.44	6.6	7.42	54.64	2.89	2.47	0.21	0.62
320	9661	1.79	4.86	4.91	65.18	0.89	3.12	0.89	0
325	9750	0.8	10.26	7.47	53.64	0.3	0.9	0.4	0
360	10424	1.1	7.69	5.49	59.33	0	2.56	0	0
375	10716	3.08	6.65	4.71	59.84	1.11	2.2	0	0
410	11397	1.78	7.14	5.36	48.21	1.78	8.93	0	0
425	11612	3.2	6.5	11.69	46.74	1.3	1.3	1.3	0
460	12026	25	7.29	11.45	17.71	3.12	9.36	2.08	0
475	12204	13.26	6.12	6.12	10.2	3.06	7.14	0	0
510	12611	5.89	5.88	9.41	1.76	15.29	11.18	0	0.59
525	12778	1.44	10.87	10.87	17.39	7.97	4.35	0	0
575	13333	13.55	2.57	13.32	14.01	8.64	11.21	0	0
610	14065	10.97	3.92	10.2	5.09	8.23	5.49	0	0
625	14488	12.87	6.6	8.91	4.29	0	3.63	1.32	0
660	15477	4.81	5.34	4.8	0.8	0.8	1.07	0.27	0
675	16104	6.85	5.39	7.87	0.44	0.44	1.31	0	0
715	16158	8.32	5.02	4.84	1.45	0.36	1.82	0	0
725	16291	8.28	9.61	7.38	3.13	0	0.67	0	0
760	16848	7.32	4.88	26.82	2.44	0	4.88	0	0
775	17086	20.1	4.89	8.69	3.25	1.08	1.63	0	0
805	17563	8.9	5.34	5.69	13.87	0.71	1.07	0	0
825	17736	18.24	7.16	4.88	3.9	0.98	0.98	0	0
850	17808	9.87	12.42	10.5	3.18	0	0	0.32	0
875	17880	11.66	10.31	13	3.13	1.79	0	0	0
905	18041	10.74	8.89	12.41	1.85	1.11	0.37	0.37	0
925	18169	11.45	10.9	7.58	1.47	0	0.55	0.18	0
950	18330	7.41	20.12	3.35	2.73	0	0	0.3	0
975	18491	10.02	7.53	11.55	3.05	0.22	1.31	0	0

Pollen sum total dry land pollen plus Cyatheaceae spores. Selected taxa shown only

(Extension of Table 3.)

URTIC-ACEAE/ MORACEAE	*Myrsine*	GRAMIN-EAE	CYATHE-ACEAE	*Dicran-opteris*	*Pteridium*	*Lyco-podium cemuum*	Pteridophyta as % of total pollen	Charcoal as % of total pollen	Phytoliths
7.96	0.88	0.88	6.19	2.65	7.08	18.58	99.26	No data	No data
0	3.92	11.76	6.37	6.37	23.04	65.2	231.82	27.94	Anvil, carbonised
10.24	0	20.47	10.24	0.79	7.87	7.1	100.88	22.05	Panicoid, anvil, carbonised
5.34	2.2	0.31	3.77	1.57		12.26	211.95	No data	
35.32	1.7	6.38	5.11	39.14	15.74	296.6	660	29.36	Panicoid, anvil, carbonised
5.69	2.6	19.05	4.76	19.92	1.14	1119.05	1385.9	19.48	Panicoid, anvil, carbonised
1.91	0.76	20.62	6.48	1.14	9.54	2.67	69	62.98	Panicoid, anvil, carbonised
11.86	0	10.17	5.08	1.69	0	1.69	41.38	No data	
5.17	3.97	2.39	7.16	0.99	1.39	2.58	46.47	3.38	Panicoid, anvil, carbonised
0.97	0.97	60.2	6.97	0	0	0.97	43.56	No data	
1.31	1.5	21.01	6	0.94	9	7.5	51.7	14.82	Panicoid, anvil, carbonised
4.57	4.77	0	2.39	1.99	0	6.16	244.29	0.2	Absent
2.03	0.76	0.89	0	0	0	0.13	65.19	"	"
0.53	0	0	0	0	1.07	0	25.64	"	"
1.41	0.7	0	1.76	0.7	0	0	86.94	"	"
0	0.83	0.83	0	0	0	0	37.1	"	"
0	5.48	0	0	1.37	0	0	72	"	"
2.32	1.74	0.58	17.48	0.58	0	13.95	355.28	"	"
0.99	2.65	0.33	6.95	0.33	0.33	3.64	239.93	"	"
1.61	0.8	0.4	2.82	0.4	0.4	1.81	174.55	"	"
1.24	0.62	0.41	3.5	0.62	0	2.26	149.7	"	"
0.89	1.78	0	2.68	0.45	0	0	193.64	"	"
0.7	1.89	0.4	3.49	0	0.7	1.69	203.06	"	"
0.37	2.2	0	5.13	0.39	0	0.78	262.81	"	"
0.28	1.11	0.55	0.28	1.38	0.8	0.55	189.47	"	"
0	0	0	3.57	0	0	0	320.34	"	"
1.3	2.6	0	3.9	0	0	0	127.5	"	"
0	9.37	1.04	3.12	0	0	0	184.76	"	"
2.04	2.04	1.02	3.26	1.02	1.02	0	101.92	"	"
3.53	6.47	0.59	0.59	0	0	0	21.57	"	"
0.72	3.62	0.72	0	0	0	2.84	58.45	"	"
0.7	9.11	0.47	15.42	0.7	0.23	0	75.83	"	"
1.57	8.23	5.49	14.51	0.39	0	0.39	61.24	"	"
0	14.85	5.94	14.95	0	0	2.31	44.03	"	"
0.27	5.33	7.46	41.06	0.27	0	0.27	80.57	"	"
1.17	18.69	8.91	34.83	2.04	0	0.73	98.51	"	"
0.99	9.41	10.05	36.47	5.39	0.27	1.64	103.41	"	"
0.67	10.74	19.24	12.52	0.22	0	1.56	40.24	"	"
0	9.76	0	12.2	0	0	12.19	21.02	"	"
0	14.67	3.8	21.73	0.54	0	0.54	41.54	"	"
0	12.1	18.85	9.6	2.13	0.36	0.36	87.88	"	"
0	15.63	1.95	20.52	0	0	0	54.94	"	"
0	7	0.32	28.65	3.18	0.32	0	56.41	"	"
0	9.86	1.35	20.18	0.45	0	0.45	48.89	"	"
0.18	13.89	0.92	28.15	1.67	0.18	0.18	59.7	"	"
0.55	11.83	0.18	37.89	2.4	0	0.37	142.98	"	"
0.91	8.23	9.14	20.42	3.96	0	0	132.35	"	"
0.65	8.06	10.67	32.01	2.18	0	1.31	107.9	"	"

are more commonly associated with dry-land cultivation, although not necessarily of rice, and were not among the 378 plant collections made in the field.

A large percentage of microfossil charcoal occurred in the uppermost sample, which may date to around 892 B.P. Anvil-shaped phytoliths probably from grasses were present back to c. 4690 B.P., and phytoliths with carbon inclusions also occurred in this sample. So burning of grasses did occur. This lends support to the theory that the disturbance was of anthropogenic origin, although not necessarily for agriculture.

The findings from Pea Bullok are intriguing, and the site deserves to be cored again so that the last 8000 years of the record can be investigated in more detail, but they give no circumstantial or substantive evidence for early rice cultivation and will not be discussed further.

Pea Sim-sim

The earlier work on Pea Sim-sim (Maloney 1979, 1985), which is also at about 1400 m altitude, suffered from the same problem as that on Pea Bullok: insufficient sample resolution at the top of the core. Counting more samples has added to the story, but there is a need for still greater resolution. Counts of microfossil charcoal and phytoliths are still required from some levels, and there is a need for more radiocarbon dates. The Pea Sim-sim record covers the period from 18,000 B.P. to present (Table 3). The early-middle Holocene spectra are not too dissimilar from those of Pea Bullok, showing the dominance of Lower Montane Forest, but Eugenia declined abruptly around 6500 B.P. This had been attributed to the final, major, phase of forest clearance, clearance of swamp forest at the site, when dry-land forest had probably already been removed (Maloney 1979). It is now clear that *Eugenia* must have been a component of the dry-land as well as the swamp forest of the region and that more detailed analyses of several sites will be needed to trace when it declined on different parts of the plateau. At present, the decline does not look to be synchronous despite the uniformity of soils, so climatic change is a less likely explanation than the more erratic impact of people. The pollen analyst can only assess the fossil record in terms of possibilities and not probabilities to reach a hypothesis which may require additional pollen research or supporting evidence from other sources.

While *Eugenia* did decline abruptly at Pea Sim-sim around 6500 B.P., it revived briefly about 3500 B.P. and 833 B.P. So, there were forest recovery periods. Additionally, oak *(Quercus)* increased when *Eugenia* declined 6500 years ago and remained important until after 3000 B.P. Some writers argue that oak can be a secondary forest taxon and therefore the vegetation might have remained disturbed, but there were still trees in the area. From about 3700 B.P. to 3500 B.P., *Castanopsis/Lithocarpus*, another Lower Montane Forest taxon, was significant. These fluctuations are suggestive of ecological instability, of vegetation disturbance which it is difficult to relate to climatic change. Therefore it is not inappropriate to think in terms of human impact, but, of course, there is no archaeological record that old from the area.

It is notable that when *Eugenia* decreased to its lowest percentage, *Engelhardia*, a possible regrowth taxon which regenerates following fire, reached a peak, but the samples from this section of the diagram have not yet been reexamined for

microfossil charcoal, so there is not a proven fire record although the low pteridophyta-to-pollen ratios until 3500 B.P. are suggestive of quite dry conditions, at least locally (apart from the tree ferns, pteridophyte spores seem to have a very localized dispersal capability). Urticaceae-Moraceae, which are common disturbance indicators, increased too, reaching a peak around 3500 B.P.

The 3500 B.P. sample had a very high pteridophyta-to-pollen percentage, while *Lycopodium cernuum*, a wet-indicating clubmoss, also increased, revealing a change to wet conditions on the swamp at least. It is not possible to say if this was of regional extent and if climatic change rather than human activities caused the vegetation perturbation. As Lower Montane Forest elements declined, gymnosperm pollen, for example, *Dacrydium*, became generally more significant. No gymnosperms were present in the remnant forest and they do not occur on the plateau today, although the Batak value their wood for making furniture and coffins (looking after the remains of the dead is a very important part of Batak sacred ritual). Gymnosperm pollen tends to be well-dispersed, and the increase in this pollen between 3500–1500 B.P. and 500 B.P. to present is suggestive of open conditions. Other changes in this part of the diagram confirm this. Open conditions could either represent climatic dryness or anthropic forest clearance.

The first Pea Sim-sim pollen diagram published (Maloney 1980) excluded the supposed swamp grass pollen grains, those of less than 23 microns in diameter, from the pollen sum. In hindsight, this was unwise and they have been included in the pollen sum here (Table 3). Inclusion accentuates the evidence for three possible forest clearance phases when rice or some other crop could have been cultivated. These phases of grass dominance are from 3500 to 2500 B.P., possibly more correctly, 2570–2500 B.P., 2167–2000 B.P., and 500–167 B.P., and (Table 3) there is evidence for dry-land regrowth, including possible regrowth of Lower Montane Forest (with *Eugenia* around 833 B.P.) overlapping these. The data from all the sites discussed have been assembled in Table 6.

Perhaps the most important regrowth curve is that of *Macaranga*. *Macaranga* can be a small tree of undisturbed Lower Montane Forest, but here we have significant peaks from 2167 to 2000 B.P. coeval with grass pollen dominance, and in very recent times. In the earliest grass-dominated phase disturbances indicating Urticaceae-Moraceae were also quite significant, but these reached their maximum around 1167 B.P., remaining important until 500 B.P. So the pattern that the pollen record is showing is of clearances accompanied by forest regeneration, what one might expect if there was shifting cultivation of dry rice.

Pteridium aquilinum spores first occurred more than 4000 years ago but were not frequent. They can only disperse very locally and they increased in percentage briefly at the beginning of the first phase of grass dominance around 2570 B.P., later overlapping the end of the second and latest phases of grass dominance. *Pteridium* normally reproduces from rhizomes, regrowing rapidly after burning. Whether or not burning also leads to setting spore is not resolved, but it is possible that the increased presence of bracken spores may be indicative of regrowth after burning, and of course burning is associated with both *ladang* and *sawah* prior to and after cultivation. Bracken was regrowing following dry-rice cultivation of the crater slopes around Pea Sim-sim and where the scrub had been burned in 1974. So, the bracken record substantiates the hypothesis advanced here. Where *Pteridium* is present, *Dicranopteris linearis* is often to be found in association. At Pea

Sim-sim *Dicranopteris* spores are most frequent at the end of the second and third phases of grass dominance. Additionally, although the data are not continuous, there are associated charcoal peaks. What is most interesting is that the pteridophyta-to-pollen ratios and, especially, the *Lycopodium cernuum* peaks indicate that conditions in the swamp were quite wet despite the peaks of dry-indicating fern spores. So, the *Pteridium* and *Dicranopteris* spores probably came from dry-land clearings on the crater slopes and were washed in rather than blown in, not from the swamp itself.

Microfossil charcoal and phytoliths data are now only available from the newly counted samples from this site, but all the samples counted earlier are now being reexamined for both charcoal and diagnostic phytoliths. Charcoal was most frequent in the 60 cm sample where the second grass pollen peak occurred, but without data from levels yet to be counted, no conclusions can be reached.

While not equivocal, the circumstantial evidence seems to point to three phases of *ladang*, perhaps the most positive evidence we have so far for shifting cultivation spanning prehistoric to almost historic times from the Southeast Asian tropics. It should be possible to detect *ladang* extending back over 2500 years at Pea Sim-sim because of the nature of the site: a volcanic crater with gentle slopes surrounded by fields that are or have been used for dry-land rice cultivation in the recent past and a swamp so deep that bracken and the like will not even grow at the drier edges.

It must be noted that pollen in the size range of rice and with a similar surface patterning was present from Late Quaternary contexts but occurred more frequently from c. 2600 B.P. onward. Rice pollen disperses extremely locally in the atmosphere but could be washed in from further away.

Pea Sijajap

Pea Sijajap is another small, almost totally infilled volcanic crater, but it is at about 1300 m altitude in a downfaulted rift valley, not on the plateau. At the time of coring, a very small area of unreclaimed herbaceous swamp existed at the center of the site, surrounded by wet-rice fields and low scrub vegetation on dry land beyond that. Four radiocarbon dates have been obtained from the upper 1.15 m of the short core, but the uppermost one is inverted.

Most of the samples are dominated by *Eugenia*-type pollen (Table 4), but *Altingia excelsa* is the most frequent pollen type in the lower three samples. The pollen record gives an impression of a site surrounded by Lower Montane Forest for the last 4000 years. Indeed, above 95 cm it is similar to the Holocene section of the Pea Sim-sim diagram predating 6500 B.P., which has no evidence for vegetation disturbance. However, the presence of an inverted date of 2000 $\pm$ 75 B.P. over one of 1815 $\pm$ 60 B.P. in the upper part of the record indicates that there was soil erosion on the crater slopes and inwash of older organic material. In view of the evidence from the other sites, it is difficult to conclude that the soil erosion was of natural origin.

The *Altingia* revival in the upper part of the diagram probably dates to about the same time as at Pea Sim-sim. The c. 3198 B.P. sample showed a minor increase of gymnosperm pollen and therefore possibly more open conditions and a more significant rise of *Quercus* as the *Altingia* declined. Regrowth following disturbance

Table 4. Pea Sijajap Core: Estimated Ages, Selected Pollen and Pteridophyte Spore Taxa, Microfossil Charcoal Percentages and Phytoliths

Depth (cm.)	Estimated age (yrs B.P.)	GYMNO-SPERMS	*Casta-nopsis* comp.	*Quercus* comp.	*Eugenia* comp.	*Engel-hardia*	*Altingia excelsa*	*Maca-ranga*	*Trema*	URTIC-ACEAE/ MORACEAE	*Myrsine*	GRAMIN-EAE	CYATHE-ACEAE	*Dicran-opteris*	*Pteridium*	*Lyco-podium cernuum*	Pteridophyta as % of total pollen	Charcoal as % of total pollen	Phytoliths
5	181	0.46	10.49	4.66	34.5	0.7	11.19	3.03	1.3	1.63	3.03	5.91	2.8	0.46	0	0.93	102.14	5.04	Panicoid, chloridoid, etc., carbonised
15	544	0.46	12.02	6.6	25	0.23	6.13	2.59	1.2	0.94	2.36	24.76	3.3	0.46	0.46	1.61	136.34	37.34	Panicoid, chloridoid, etc., carbonised
25	907	1.25	13.17	4.97	31.11	0.97	8.53	1.46	1	3.31	3.41	23.91	2.14	2.63	0	2.05	140.24	50.78	Panicoid, chloridoid, etc. carbonised
35	1270	0.85	10.66	4.75	31.7	1.3	10.37	0.58	0.3	2.3	4.03	9.22	1.44	1	0	2.16	120.83	38.76	Panicoid, etc., carbonised
45	1633	0.93	10.97	6.03	31.84	0.15	11.9	0.92	0.5	1.7	5.25	7.57	1.39	0	0	1.39	138.05	23.64	Panicoid, chloridoid, etc., carbonised
55	1975	1.23	9.43	3.69	31.47	0.82	13.11	0.41	0.4	4.92	2.05	6.14	1.64	0.82	0.4	2.46	135	27.87	Panicoid, etc., carbonised
65	2135	0.96	8.74	4.78	33.06	0.41	9.29	1.37	0.6	3.68	4.37	10.24	3.14	0.55	0.2	1.37	109.4	19.26	Panicoid, chloridoid, etc., carbonised
75	2604	0.99	10.91	6.22	29.75	1.89	10.82	0.63	0.6	1.35	3.43	8.29	1.89	2.61	0.4	2.52	122.33	32.01	Panicoid, chloridoid, etc., carbonised
85	2901	4.07	8.37	10.18	25.11	0.68	17.65	1.36	0	1.59	7.01	1.36	4.52	0.45	0.8	0.46	276.24	220.13	Panicoid, sparse
95	3198	4	6.08	12.88	20.45	0	22.7	0	0	2.27	2.27	2.27	2.27	2.27	0	0	172.87	20.52	Absent
105	3495	1.53	4.3	8.14	8.39	0	40.97	0.25	0	0.5	17.3	0.76	1.27	0.3	0.3	0	88.14	Trace	Absent
115	3940	0.89	4.28	7.84	14.97	1.25	25.49	0.53	0	2.13	10.16	2.13	0.53	0	0.6	1.18	89.96	42.06	Panicoid, sparse

Pollen sum total dry land pollen plus Cyatheaceae spores. Selected taxa shown only.

Table 5. Tao Sipinggan: Estimated Ages, Selected Pollen and Pteridophyte Spore Taxa

Depth (cm.)	Estimated age (yrs B.P.)	GYMNO-SPERMS	*Casta-nopsis* comp.	*Quercus* comp.	*Eugenia* comp.	*Engel-hardia*	*Altingia excelsa*	*Maca-ranga*
0		0	0	7.79	18.18	2.6	0	1.3
10		0	2.94	9.8	2.94	0.98	0	0.98
25		0	2.04	4.08	2.72	1.36	0	0.68
135	74	5.01	3.49	13.17	3.76	2.82	6.58	2.51
145	222	2.05	5.33	24.59	16.39	2.87	0	4.51
160	444	5.79	0	6.31	1.05	1.58	4.74	0.53
180	740	11.31	2.98	7.74	0.59	2.38	7.74	1.19
225	1109	5.68	3.41	19.32	2.27	0	6.82	3.41
255	1405	6.61	4.13	14.88	9.92	4.96	8.26	1.65
275	1701	4.3	2.15	30.11	8.6	7.53	4.3	3.23
300	1931	4.29	2.86	28.57	32.86	1.43	0	0
310	2123	6.62	3.68	25.73	19.85	2.2	5.15	1.47
330	2307	3.5	0.7	24.47	2.1	30.07	3.5	0.7
355	2445	2.86	1.43	24.28	18.57	0	5.71	0
380	2675	4.08	4.08	40.81	13.26	2.04	5.1	2.04
410	2951	3.26	6.52	32.61	8.7	14.13	5.43	4.35
425	3089	4.57	7.84	33.33	8.5	14.38	7.84	0
440	3227	2.25	3.37	29.21	7.86	15.73	2.5	3.37
455	3365	6.06	9.01	31.82	4.54	5.3	3.79	3.03
470	3503	1.03	6.18	34.02	12.37	9.28	5.15	7.22
505	3825	6.01	4.37	39.89	2.18	13.11	6.01	1.09
540	4147	9.22	2.13	30.5	3.55	7.09	10.64	0.71
570	4423	6.67	1.9	54.29	0.95	10.48	1.9	1.9
595	5089	7.5	3.75	25	13.75	11.25	6.25	0
605	5340	5.13	0	10.26	51.28	0	0	0
630	5968	4.22	5.42	16.87	36.14	3.61	2.41	0
645	6345	4.54	4.54	15.91	20.45	3.41	3.41	4.54
660	6721	6.59	2.99	13.17	35.33	2.99	0.6	2.4
690	7474	9.72	6.94	20.83	9.72	2.78	1.39	0
710	7976	7.06	5.82	39.53	7.06	11.29	2.36	1.18
730	8478	0	5	27.5	20	2.5	10	0
750	8980	13.25	4.82	21.69	1.2	19.28	7.25	1.2
765	9234	1.1	21.97	0	2.2	2.2	4.39	0
780	9749	10.14	14.49	11.59	5.8	4.35	8.7	0
810	10437	6.33	5.06	27.85	7.59	10.13	8.86	1.26
840	10778	9.4	5.37	29.53	6.04	14.09	5.37	2.01
870	11119	5.85	11.11	22.81	4.68	8.19	6.43	1.17
900	11459	20.11	8.94	12.85	8.94	17.32	8.94	0.56
910	11573	27.56	9.92	22.05	6.61	3.31	16.53	0
920	11687	22.27	10.89	15.35	8.41	4.45	7.42	0
922	12167	22.36	4.97	10.56	4.35	28.57	3.1	1.24

Pollen sum total dry land pollen plus Cyatheaceae spores.
Selected taxa shown only.

(Extension of Table 5.)

Trema	URTIC ACEAE/ MORACEAE	*Myrsine*	GRAMIN- EAE	CYATHE- ACEAE	*Dicran- opteris*	*Pteridium*	*Lyco- podium cernuum*	Pteridophyta as % of total pollen
0	3.9	0	42.86	0		5.19		
0.98	6.86	0	62.74	0.98	0.98	6.86	35.29	43.55
0	4.08	0.68	78.23	1.36	3.4	2.72	31.97	54
2.82	7.52	1.25	26.01	0	1.57	1.57	1.25	58.48
0.41	6.97	1.64	6.15	4.1	0.82	2.05	0.82	91.94
2.1	9.47	1.58	45.79	2.1	0.53	1.05	0.53	21.53
2.38	8.33	0.59	42.26	1.19	1.19	2.98	1.79	83.53
2.27	10.29	0	6.82	6.82	1.14	2.27	3.41	137.11
3.31	4.13	0.83	23.97	0	0.83	3.31	0	77.94
4.3	4.3	1.07	4.3	2.15	1.07	0	1.07	103.19
0	1.43	1.43	1.43	0	1.43	0	0	59.05
0	11.76	0.73	8.09	0	0	0	0	65.4
2.8	10.49	0	0	3.5	0	0.7	0.7	42.21
1.43	2.86	5.71	0	0	0	0	0	169.32
1.02	0	2.04	0	1.02	0	0	0	95.75
1.09	0	0	0	0	0	0	0	59.26
0	0	0	0	1.31	0	0	0	95.57
3.37	5.62	0	0	0	0	0	0	150.09
2.27	4.54	0.76	0	1.51	0	0	0	134.82
0	0	0	0	5.15	0	0	0	115.38
0	1.64	0	0	1.09	0	0	0	69.81
0	9.22	0.71	0	0.71	1.42	0	0	66.67
1.9	0	0.95	0	0.95	0	0	0	126.27
0	3.75	1.25	0	12.5	1.25	0	0	166.67
0	2.56	2.56	0	5.12	5.12	0	0	356
0	1.81	3.01	0	8.43	1.2	0	0	209.52
0	1.14	0	0	10.23	6.82	0	0	278.4
0.6	4.19	5.99	0	4.19	0.6	0	0	200
0	6.94	0	0	4.17	0	0	0	281.08
1.18	8.23	0	0	5.88	2.36	0	0	187.5
2.5	0	0	0	2.5	0	0	0	102.32
0	6.02	0	0	4.82	2.41	0	0	150.55
0	3.3	0	0	60.44	1.1	0	0	451.28
1.45	0	0	0	7.25	4.35	0	0	140.79
0	5.06	0	0	8.86	5.06	0	0	138.37
0.67	5.37	0	0	3.36	2.01	0	0	144.02
1.75	11.11	0.58	0	1.75	0	0	0	66.67
0	0	0	0	2.23	0.56	0	0	64.97
0	2.2	0	0	7.72	3.3	0	0	109.16
0	1.98	0.49	0.49	0.49	0.49	0	0	45.41
0.62	1.24	0	0	3.1	0	0	0	66.46

may be represented, but *Macaranga* and *Trema* are absent and the pteridophyta-to-pollen ratio is high, suggesting a change to wetter conditions. The swamp seems to have been quite dry however.

The c. 2901 B.P. sample had a very high charcoal percentage, and the *Engelhardia* percentage increased in around 2600 B.P. This could be evidence for regrowth following fire. Phytoliths from the Chloridoid and Panicoid subfamilies of the Gramineae present had carbon inclusions, so they derive from burned grasses, and the grass pollen percentages were rising and this could relate to agricultural activity.

Eugenia continued to have a high percentage around 2135 B.P. despite the peak of open-indicating grass pollen and the rise of Urticaceae-Moraceae, but other Lower Montane Forest elements and the gymnosperms declined, indicating forest retraction. The pteridophyta-to-pollen ratios suggest that conditions may have continued to be quite wet locally, however, but not as wet as around 3500 B.P. Microfossil charcoal was less abundant though. The upper part of the diagram is difficult to interpret because of the inverted radiocarbon date, but despite the high Lower Montane Forest tree pollen percentages, there was disturbance of the vegetation, evident by peaks in the Urticaceae-Moraceae percentages and Gramineae in samples, which may date to between 907 and 544 B.P. Regrowth *Macaranga* and *Trema* reached peaks at the top of the diagram. This cannot be tied in with historical data for recent land abandonment, although *Macaranga*, but not *Trema*, showed a similar pattern at Pea Sim-sim, partly because the estimated ages of samples could be incorrect. All of these samples contained Chloridoid and Panicoid phytoliths with carbonized inclusions, so vegetation burning was continuing to occur and shifting cultivation could have been practiced.

To summarize, here we seem to have evidence for two forest clearance phases, probably for agriculture, postdating about 2600 B.P., as at Pea Sim-sim, but the case for *ladang* is less clear. *Dicranopteris* does have peaks at 75 cm and 25 cm depths, but bracken is inconspicuous. It is possible that rice was grown on the swamps, as it was in 1974 in the Simamora Valley, but it would be very difficult to prove this. There is more evidence that *ladang* did not occur and indeed in 1974 the site was surrounded by *sawah*.

Pea Sijajap has low percentages of Amaranthaceae pollen in the 115 cm and 105 cm samples, preceding any strong evidence for vegetation disturbance and possible agriculture, as well as in the 5 cm sample, which has a spectrum more suggestive of agriculture. The most complete microfossil charcoal and phytolith records are from this site. The charcoal record is very important as it suggests that vegetation disturbance, including burning of grasses, was taking place despite the dominance of tree pollen throughout the available record.

Tao Sipinggan

Tao Sipinggan (c. 1400 m) is another extinct crater located on the plateau and has steep sides, but some level (or leveled) land surrounds the lake. The core analyzed (Table 5) was extracted through a floating mat at the south end of the site and consisted largely of organic material as a swamp forest seemed to have been present at the lake margin in the past, but fields were later constructed when this was removed. The upper part of the sublake surface stratigraphy contains Toba tuff

eroded from the steep crater slopes following forest clearance, presumably before the 30 cm thick floating mat formed.

Three pollen spectra from the floating mat were subjected to pollen analysis, and all three were dominated by grass pollen but contained significant percentages of tree pollen and of *Pteridium* spores, the latter almost certainly locally dispersed from the steep crater walls. Little more can be said about these samples as the age of the lowermost is unknown except to say that they contain much higher grass pollen frequencies than the upper lake sediment sample and rather less tree pollen grains.

Tao Sipinggan has significant percentages of disturbance indicating *Macaranga, Trema,* and Urticaceae-Moraceae in the lower part of the diagram, particularly the 870 cm sample, which is about 11,120 years old. This is above an inverted radiocarbon date of c. 12,380 at 900–910 cm, suggestive of disruption of vegetation and inwash of old carbon from nearby slopes. Here the soil erosion is almost certainly of natural origin and indicates that interpretation of the vegetation history must be made with care. To illustrate this further it must be pointed out that a brief but dramatic vegetation perturbation occurred around 9230 B.P.: there was an isolated, large, peak of regrowth Cyatheaceae exceeding 60 percent, which was preceded and followed by more minor peaks of *Dicranopteris.* The simplest explanation of this change is earthquake disturbance. Hehanussa et al. (1987) stated that substantial movement along faults ended about 17,000 years ago, but Braak (1929) reported that an earthquake had taken place in 1921. However, the rather high *Engelhardia* percentages before and after this event could suggest burning of the vegetation, but microfossil charcoal has still not been counted.

Engelhardia was also high in the 710 cm sample, which could be 8000 years old, as was open-indicating Urticaceae-Moraceae pollen, which continued to be significant for another 2000 years. Comparison with the other pollen records of this age leads more and more to the conclusion that the pattern of disturbance is not of natural origin, but *Eugenia* was important, in association with oak, around the lake from around 6700–5100 B.P., when *Engelhardia* increased again, and remained of importance until c. 3000 B.P. During this phase, and until recent times, oak became the most important tree pollen type, although *Eugenia* did not decline in the same manner as at Pea Sim-sim and was significant between 2660 and 1930 B.P.

At first sight, the almost continual oscillation in the pollen curves is baffling, but where this pattern occurs it is usually the result of vegetation instability. The problem is determining the cause of this instability. To explore this further, we must look at the *Macaranga, Trema,* grass, Urticaceae-Moraceae, *Dicranopteris,* and *Pteridium* data, as these taxa are all important disturbance indicators. The most dramatic changes take place in the percentages of the latter three. The first Gramineae peak occurs abruptly around 2120 B.P. when oak and *Eugenia* were increasing. It was preceded by *Engelhardia* percentage of more than 30 percent, which might relate to recovery of forest after burning, but which cannot be verified due to lack of microfossil charcoal counts.

The second grass peak was at c. 1400 B.P. and was important, leaving oak (possibly regrowth) as the only major tree-pollen contributor, and the third peak, the largest, was between 740 and 440 B.P. The final rise was in the uppermost sublake sample and was of recent age. Urticaceae-Moraceae percentages might be expected

to increase where grass pollen percentages decrease. In fact, they rose with the first rise of grass pollen and between 1400 and 740 B.P. when grass declined, but increased Urticaceae-Moraceae frequencies usually accompanied increased grass percentages.

Pteridium entered the record with the first grass peak, at a background level, while *Dicranopteris* was absent until after this and was then ever-present, although never important. *Pteridium* reentered during the second grass peak and was more significant, possibly indicating the occurrence of burning thereafter. The presence of both the spore types, dry indicators, overlap those of wet-indicating *Lycopodium cernuum* from about 1100 B.P. onward. The latter probably derive from vegetation surrounding the lake and the former from the crater slopes. *Macaranga* percentages increased at 1700 B.P. and 1100 B.P. when oak also revived, but *Trema* mirrored the grass peaks better.

So, there is evidence for very disrupted vegetation. The changes take place so rapidly that it would be difficult to attribute them to response to climatic change, although earthquake activity cannot be ruled out unless we accept the conclusions of Hehanussa et al. (1987). In this instance, if rice was cultivated, it would not be surprising if it was as *ladang* on the crater slopes for the last 2000 years, as it was still in the early 1970s, and around the lake as a wet-land crop. Pollen in the size range of rice and with a similar surface patterning was present from the first grass peak onward (Maloney 1990). No microfossil charcoal or phytolith counts were made, but the original samples are now being gradually reexamined as time permits.

DISCUSSION

The reason for the detail given above is that the palaeoecological record from each site has its own complexities and not including it would leave the writer open to the charge of oversimplification and trying to make the data fit the conclusions that are drawn here. This problem is not confined to interpretation of tropical sites, but occurs generally. The fossil record is not easy to interpret. There are no clear-cut answers because there is no simple cause and effect. There are usually causes and effects and the analyst needs to weigh the possibilities against each other to come to a balanced conclusion to be left for others to test. It makes for tedious reading, but this is the method of science.

So, the evidence from the pollen record suggests that North Sumatra may have been occupied before the proposed first arrival of the Batak, or that they may have arrived earlier than has been supposed, whether they came from the east or west. Whether or not swiddening began around 8000 B.P. and what was grown is difficult to say. Even in the ever-wet tropics, charcoal evidence may not necessarily be the result of human-induced burning (cf. Johns 1986). Natural forest fires dating from about 17,500 to 350 B.P. occurred in eastern Kalimantan (Goldammer and Seibert 1989), while mid- to late-Holocene fires have also been reported from areas without (as yet) known human settlement in Amazonia (Sanford et al. 1985). Additionally fires can be started to entrap game, to extend the grazing land for ungulates, or to promote the growth of more nutritious pasture grasses.

The development of dry-land cultivation involves improving sustainability through using better agricultural management techniques with existing crops, in-

Table 6. Generalized Dates (Estimated Years B.P.) For Phases of Grass Dominance in the Toba Plateau Pollen Diagrams

PEA SIM-SIM	TAO SIPINGGAN	PEA SIJAJAP
2570–2500		
2170–2000	2120	
	1400	
		900
	700–440	
500–170		540

troducing new higher-yielding crop plants (e.g., the sweet potato in Papua New Guinea), or improving the varieties of older crop plants. The increase in vegetation disturbance after about 2500 B.P. reported upon here is, curiously, mirrored at Kuk (Bayliss-Smith and Golson 1992) and could suggest that the population was expanding, that there might have been in-migration of a new people (possibly Austronesian speakers), possibly bringing a new crop (perhaps rice), or a changed economy (movement of rice without significant human migration?). That movements of people into the area did take place in the past is shown (McKinnon 1991*a*) by the fact that the Batak are not ethnically homogeneous.

The evidence for forest decline does not occur at the same time in any of the sites considered above, and the pattern of change differs at each. This is what can be expected if the changes were of anthropogenic origin, due to the activities of shifting cultivators, instead of due to climatic change when more unified vegetation responses might be expected, especially at the plateau sites, all of which are at a similar altitude.

Until all the samples have been reinvestigated for microfossil charcoal and diagnostic phytoliths it is most useful to summarize and conclude by looking at the grass pollen records again. The earliest phases of grass prominence in the pollen diagrams occurred at Pea Sijajap in the Simamora Valley (Table 6) around 2600 B.P. and possibly a little later at Pea Sim-sim. The people of Lintongnihuta claim that their ancestral village was in the Simamora Valley, and there may be some truth in this, as genealogy is the foundation upon which Batak society is based. It is very important to them whether they are of Toba, Karo, Dairi, or other origin and to which *marga* (clan) they belong.

Geographical factors would not preclude irrigated rice cultivation in the Simamora Valley, but initial swamp rice cultivation is more probable, given that both were being practiced in the 1970s. The topography in the vicinity of Pea Bullok and Pea Sim-sim precludes wet-rice cultivation today, and wet-rice cultivation is unlikely to have occurred on the crater slopes in prehistory. Grass prominence in the Tao Sipinggan record appears to be coeval with the second phase of increased grass pollen at Pea Sim-sim, but another increase around 1400 B.P. is only present at the latter site. The estimated ages for the final major disturbance phase at both sites overlap with each other and that from Pea Sijajap, however, beginning around 700–500 years ago. This suggests that both a wider area of land and very different environments were used simultaneously and that because the environ-

ments are so different, land use was unlikely to be the same in the vicinity of each site.

The big question that remains to be answered is when was *sawah* introduced to island Southeast Asia? Van Setten van der Meer (1979) states that comparatively large-scale irrigation occurred in Java prior to the fifteenth century A.D. Irrigation is associated with tillage using the hoe or the plough, while cultivation of root crops and drainage of the land (Bayliss-Smith and Golson 1992) are linked with the digging stick. Early hoes and ploughs have not been reported from island Southeast Asia, but Higham (1989) suggested that the plough was introduced to Bac Bo from China in Han times with the practice of constructing bunded fields. The earliest historical information from Vietnam (Wheatley 1965) is from the Tonkin lowlands and dates to the early centuries B.C. In island Southeast Asia montane irrigation takes the form of what is referred to as pondfield irrigation in Polynesia (cf. Kirch and Lepofsky 1993) and the use of terracing. The history of pondfield irrigation in island Southeast Asia is obscure, but, like Bronson and Asmar (1976), those who mention it at all suggest that it is late. The most detailed recent studies of terracing seem to be those made in the upper Ramu River Valley of the Papua New Guinea highlands (Sullivan et al. 1986), where cut garden terraces on slopes appear to be more than 500 years old. Clearly, more information is needed, but terrace sequences are difficult to date.

The historical record for the study area began with two accounts based on travels made in 1823 and 1824 (Anderson 1826; Burton and Ward 1826). Anderson's report was largely based on hearsay evidence, but Burton and Ward reached the Silindung Valley, south of where Siborongborong is today, and described a land (p. 488) where only some mountain tops were forested, apart from sacred groves and trees planted around houses, where sweet potato (? taro, not actually sweet potato) and irrigated rice were cultivated but there is no clear mention of *ladang* from this area until page 510. Burton and Ward had hoped to travel (p. 491) as far as the great lake of Toba but eventually decided to climb the highest surrounding hill to view the land beyond Silindung and reported that each hut on the plain of Butur between Silindung and Toba had attached to it a field or patch of mountain rice (p. 493). Butur is described as being located between Toba Silindung, Toba Holbang, west of Lake Toba, and the district of Humbang (the Siborongborong area). Toba Linton, probably the Lintongnihuta region, was also described as located west of Toba and this and Toba Holbang were thought to be more populous than Silindung, which had 82 villages comprising 80,000–100,000 people. So there is support in the historical record for the interpretation of the pollen evidence given here.

According to McKinnon (1991*a*), Karo folktales mention the presence of well-armed Indian traders in the area centuries ago, and it is they who may have brought the concept of irrigation agriculture, late, to the region, while the revival of rice cultivation in Borneo in the fifteenth century (Sen 1995) might also be attributable to a late introduction of irrigation, that is, that rice was initially grown as a dry-land crop.

CONCLUSION

Clearly at this stage the results of the palaeoecological analyses outlined above add more information on the possible land use of the area over the last few thousand

years than the historical or archaeological information can give about the peoples, their origins, cultures, and economic and social structures. Such analyses are capable of providing much additional data in the future but not the proof that we would find most convincing. Archaeological excavation, with archaeobotanical investigation of any plant remains discovered, is necessary for that.

The use of the pteridophyte record by pollen analysts as an indicator of vegetation disturbance is gaining support. Ellison (1994) stated that *Dicranopteris* expanded around 2500 B.P. (that critical date again) at Mangaia in the Cook Islands when charcoal first appeared in her core, but there was no indication of what, if anything, might have been cultivated and island-wide disturbance did not begin until around 1650 B.P. *Pteridium* spores were frequent between 6200 and 5900 B.P. at the Saint Louis Lac site, New Caledonia (Stevenson and Dodson 1995), then absent until 3000 B.P., when they recurred with Gramineae and trilete pteridophyte spores. The charcoal influx followed the pattern of fern spore influx, but only the change at 3000 B.P. is ascribed to an anthropogenic cause. Again, there is no indication of what might have been cultivated. Kirch (1991 : 119) stated that shifting cultivation on Futuna, Uvea, and Samoa today involves planting aroids and yams first, then bananas and (p. 120) attributed what he called "terminal" vegetative associations of *Dicranopteris* on many high Polynesian islands to swiddening in the past. Some aroids may contribute, but not abundantly, to the pollen record, while yams and bananas are unlikely to do so.

The evidence for prehistoric land use in North Sumatra presented here is tantalizing, although rather speculative, suggesting a regional variation in the timings and intensity of vegetation disruption before recent times, possibly initially associated with hunting of animals, then cultivation of a root crop, as hinted at by the first historic account of the area, followed by *ladang* and *sawah*. There is insufficient information, however, to establish when the earliest forest clearance was made in the region or to trace the detailed pattern of disruption at any one site. The phases of grass-pollen dominance at the various sites (Table 6) indicate that major clearings possibly associated with rice cultivation began around 2600 B.P., which is in line with the theory that the Batak have been in Sumatra for upwards of 3000 years. Too much should not be read into this, however, as more refined pollen analyses are bound to reveal a complex pattern of change. If nothing else, this paper indicates the potential of palaeoecological analyses for adding to historical, if not prehistoric, detail and allowing new hypotheses to be introduced about what happened in prehistory, although in the latter respect it can only suggest possibilities, not certainties. It cannot create proxy archaeologies.

Rice could have been introduced as both a dry-land and a wet-land crop late and simultaneously, but this will be very difficult to prove palaeoecologically. The way ahead on the research front, now that we have some idea about how slowly peat and lake sediments accumulate at this altitude, is almost certainly to examine a series of short cores intensively, as Corlett (1984) did in montane New Guinea, but this would be expensive both in terms of the time it would take and the cost of extensive radiocarbon dating.

That likely dramatic disruption to the vegetation can be traced is testimony to the presence of higher populations in the past, as suggested by Burton and Ward (1826), and the marginality of the land. Despite a suitable climate, soil factors, which include shallow depth, poor drainage, and usually very acidic parent materials, probably hinder rapid tree regeneration. As the forest has been destroyed,

distance from seed sources and the presence of more readily burned herbaceous vegetation will have also played a role in keeping the vegetation open, an inherited effect.

Consideration of the pollen records from the rest of highland Sumatra and Java (Morley 1982; Newsome and Flenley 1988; Stuijts 1993) suggests that the Toba Plateau sites are especially valuable as providers of information on local land use because of their topographies and close spacing. Nothing directly comparable has been reported from elsewhere but the Kalabit Highlands of Kalimantan, a non-volcanic area, have plateau peats that could be usefully investigated, and World Wide Fund for Nature is collecting cores for analysis by myself there at present. Some of the Javan sites also deserve reexamination. There is potential for more finds to be made by further detailed analysis of cores from most of the Southeast Asian sites already studied now that we are past the pioneer stage of investigations.

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ABSTRACT

The origins of dry farming in the Southeast Asian tropics have been neglected until recently. Information from five North Sumatran pollen diagrams is summarized, with a chronological control of 41 radiocarbon dates, and it is suggested that pollen, phytolith, and microfossil charcoal evidence, viewed in the light of the local topography and more recent land use, indicates that dry rice may have been cultivated from c. 2600 B.P., possibly coeval with swamp rice, or some form of irrigated rice, depending upon the location, and that agricultural expansion in this area of largely poor soils began between 700 and 500 years ago. KEYWORDS: prehistoric rice cultivation, North Sumatra, palaeoenvironmental analysis, palynology, phytoliths, Southeast Asian archaeology.